SEASONAL VARIATION OF REAL-TIME RADON LEVELS IN A RESIDENTIAL APARTMENT UNIT IN KIAMBU COUNTY, KENYA

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Introduction

Radon (^{222}Rn) is a radioactive element in the decay chain of ^{238}U, a primordial radionuclide universally present in rocks and soil albeit in trace amounts. Unlike other decay products in the chain, radon is a gas and can therefore become airborne. If this occurs within a confined space such as a dwelling, the gas can accumulate significantly and being carcinogenic increase the risk of lung cancer among the residents. WHO recommends the adoption of radon mitigation measures when levels exceed 100 Bq/m^3 or 300 Bq/m^3 if the former is not achievable. In Kenya, indoor radon research is limited with less than 10 documented works. What is more, none of these works involve pre-cast concrete homes and real-time radon measurements. This study was carried out in a modern second-floor apartment unit of an apartment complex constructed using pre-cast concrete slabs. The complex is located within Kiambu County in an area characterised by rich red volcanic soil. The study involved real-time monitoring of radon levels with the aim of establishing the relationship between the concentration and the season.

Materials and Methods

Three rooms were studied: Room1 (7m×4m), Room2 (4m×4m) and Room3 (3m×3m) [Figure 1]. A portable Alfarad radon monitor equipped with data analysis software was used for radon measurement under CRn 60 mode in which sampling was done for 3 minutes followed by 60 minutes of counting. On completion, radon concentration and environmental parameters were displayed on the detector screen [Figure 2]. Measurements were taken twice daily, in the morning between 6.00 am and 11.00 am and in the evening between 6.00 pm and 11.00 pm, one room after the other. This was done for 18 days of each month, from May 2023 to April 2024. In total, 1,296 measurements were collected.

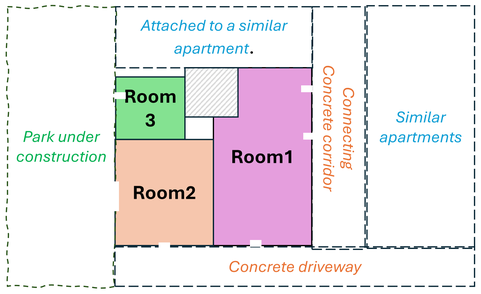

Figure 1: Sampling area

Figure 2: Portable Alfarad detector

Results

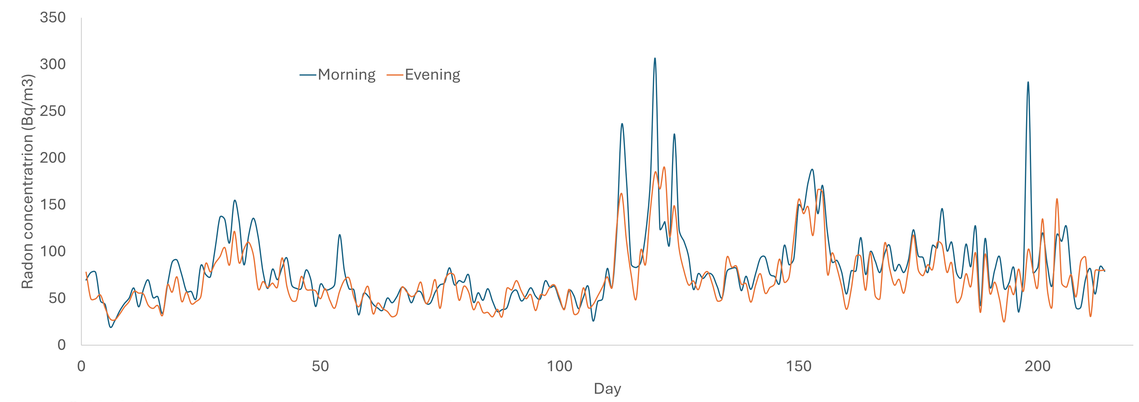

Figure 3: Variation of radon concentration with time

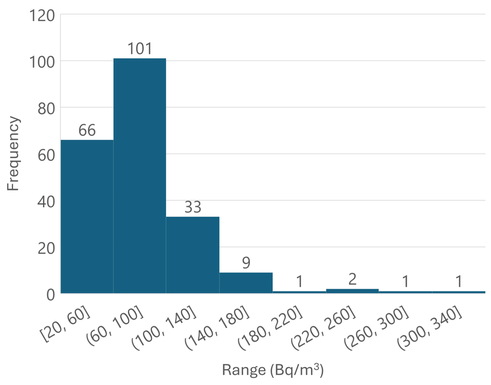

Figure 4: Frequency distribution for morning sessions

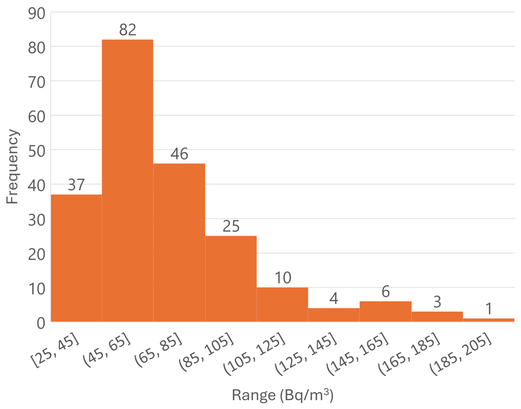

Figure 5: Frequency distribution for evening sessions

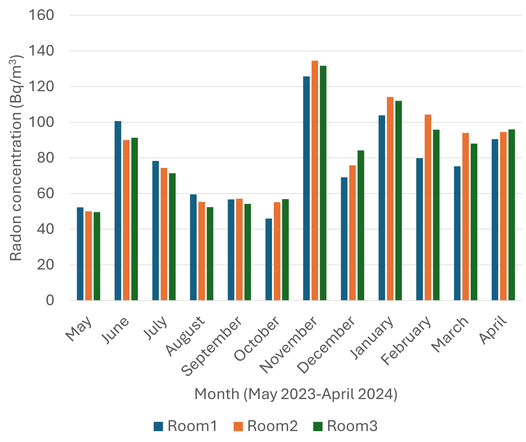

Figure 6: Variation between rooms and seasons - morning sessions

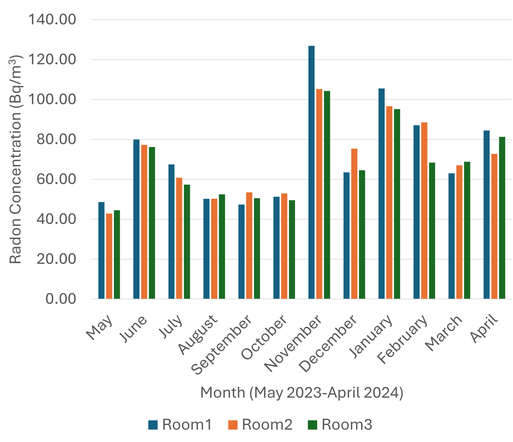

Figure 7: Variation between rooms and seasons- evening sessions

Discussion

Overall, the concentration for the entire unit ranged from 24 Bq/m^3 to 246 Bq/m^3 with an arithmetic mean of 76 Bq/m^3. As shown in Figure 3, there was no significant difference in radon levels between morning and evening though the concentration was slightly higher in the morning with an average of 81 Bq/m^3 compared to evening at 70 Bq/m^3. The lack of pronounced variation may be attributed to the moderate ventilation of the unit on account of its structural design. Of the measurements taken in the morning [Figure 4], 47 (7.2%) exceeded the reference level of 100 Bq/m^3 while 1 measurement exceeded 300 Bq/m^3. The evening saw the number of measurements beyond 100 Bq/m^3 drop to 24 with none exceeding 300 Bq/m^3 [Figure 5], probably due to increased aeration. The overall low radon levels in the apartment unit may be due to low radon exhalation rate from the pre-cast, highly compacted, concrete slabs used for construction. As evident from Figures 6 and 7, minor variation in radon levels was observed between rooms, with average concentration ranging from 69 Bq/m^3 to 82 Bq/m^3. This could be because of the relatively small size of the unit leading to good air-exchange between rooms. The fact that the unit was occupied during the research period may also have enhanced air exchange.

The season seemed to influence indoor radon concentration despite the apartment unit not being in direct contact with the soil [Figures 6 and 7]. After a long dry spell, the rains came in May through June 2023 with a spike in radon concentration observed in June with average radon level of 94 Bq/m^3 (morning) and 78 Bq/m^3 (evening). The apartment unit is adjacent to a park that was mostly bare at the time. Radon-laden soil gas displaced by rainwater may have infiltrated indoor air through openings leading to the rise in radon concentration. July through September 2023 were cold and dry for the most part. The radon concentration dipped to less than 60 Bq/m^3 on average during this period probably due to reduced soil-gas exhalation and consequently reduced infiltration indoors. November saw an un-expected heavy downpour after a relatively hot October, leading to an abrupt and significant increase in indoor radon concentration with a mean value of about 130 Bq/m^3 (morning) and 112 Bq/m^3 (evening). Another heavy downpour and a subsequent surge in indoor radon concentration was observed in January with morning and evening radon concentration averaging 110 Bq/m^3 and 99 Bq/m^3 respectively. It is important to note that the average temperature for the months September 2023 through April 2024 were hotter with an average temperature of about 26^{0}C compared to the preceding months where temperature averaged about 23^{0}C. The higher temperature alongside elevated soil moisture particularly between November 2023 and April 2024 may have contributed to the increased radon concentration which during these months averaged 98 Bq/m^3 and 84 Bq/m^3 in the morning and evening respectively. The preceding cooler months May 2023 - September 2023 recorded average morning and evening concentrations of 63 Bq/m^3 and 56 Bq/m^3 respectively.

Conclusion

In this study, indoor radon concentration was largely independent of the room and time of the day, a factor attributed to the relatively small size of the apartment unit and the low ventilation level. Climatic conditions were observed to influence indoor radon concentration with levels surging following a heavy downpour or prolonged moderate rains as soil-radon displaced from the adjacent park area infiltrated indoor air. Indoor radon level was also relatively higher in the hotter season compared to the colder one probably because of increased outdoor radon exhalation rate. With a mean of 76 Bq/m^3, the overall radon concentration was within the reference level of 100 Bq/m^3.

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